RELATION OF GEOLOGY TO STREAMFLOW IN THE UPPER LITTLE MIAMI BASIN[1]

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Water falling upon the land as precipitation is the prime source of streamflow. The pattern in which this precipitation returns to its source in oceans and lakes is dependent upon many inter-related factors affecting both the precipitation and the physical route of return. For example, precipitation on a completely impervious basin of barren rock would result in sudden runoff and frequent flooding, followed by a rapid decline in the streamflow, with little or no flow in a matter of a few days or even a few hours. On the other hand, a geographically similar basin underlain by thick permeable material would permit the infiltration of much of the precipitation to the ground water reservoir. Immediate surface runoff would be limited only to that portion of precipitation in excess of the infiltration capacity of the basin, and streams in the basin might show relatively small rises followed by lengthy periods in which the flow was maintained by seepage from the infiltrated ground water. The effect of the geology of a basin is thus reflected in its regimen of streamflow. This paper describes the relationship between the geology and streamflow in the Upper Little Miami Basin.

GENERAL HYDROLOGY AND GEOLOGY

The Upper Little Miami River above Spring Valley drains an area of 361 square miles lying principally within Greene and Clark Counties. Its topographic location is shown on figure 1. Continuous records of streamflow are available at five sites in the basin, and are among those collected and published by the U. S. Geological Survey in annual water supply papers. Locations of these sites are also shown on figure 1. Geological data are from a report on the Water Resources of Greene County by the Ohio Division of Water (Norris *et al.*, 1950), which includes sections on the geology of glacial deposits by Goldthwait, and on the geology of consolidated deposits by Norris. A series of miscellaneous streamflow measurements made by the U. S. Geological Survey within the basin on September 15, 1948, also is available.

The relation of ground water and geology is well discussed by Meinzer (1923), Tolman (1937) and others. The relation between streamflow and ground water has been studied by many different methods. Cross (1949) used a dry-weather index determined from duration of flow in Ohio streams, for correlation with ground water and geology. The discharge equaled or exceeded 90 percent of the time for the period of record was selected by Cross as an index of dry-weather flow. In this paper, the index of dry-weather flow was selected as the discharge equaled or exceeded 90 percent of the time for the period October 1953 to September 1955.

Duration curves for the period October 1953 to September 1955 were prepared by arranging all daily discharges in order of magnitude and computing the percentages of time that specific flows were equaled or exceeded. This has been done for the five streamflow stations in the Upper Little Miami Basin. The duration curve for Spring Valley for the same period was estimated on the basis of records from 1926 to 1935 and from 1940 to 1951. The resulting duration curves are shown on figure 3. The discharge at the 90 percent duration points, or lowflow indices, from these curves also are shown on figure 1. The shape of the lower end of the duration curves is indicative of the degree to which streamflow is sus-

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tained by effluent seepage from the ground water reservoir during periods of no surface runoff. This effluent seepage in turn can be related to the lithology and structure of the rocks which control the infiltration to and transmissibility of the ground water reservoir.

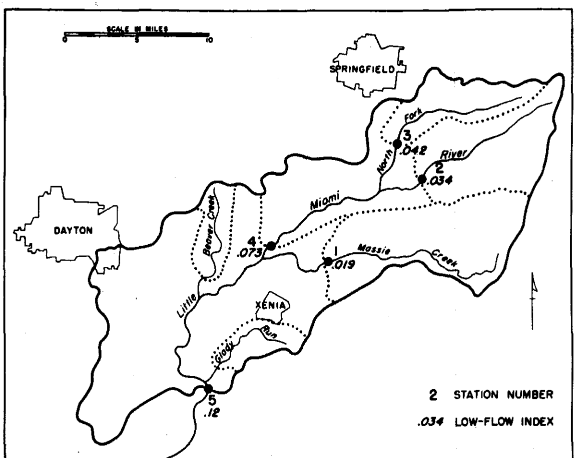

Figure 1.

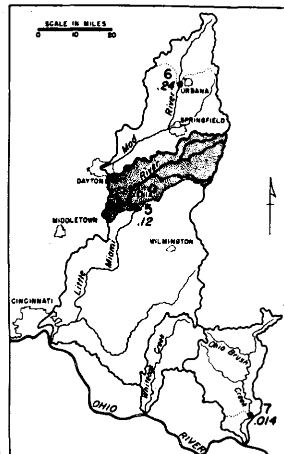

Figure 2.

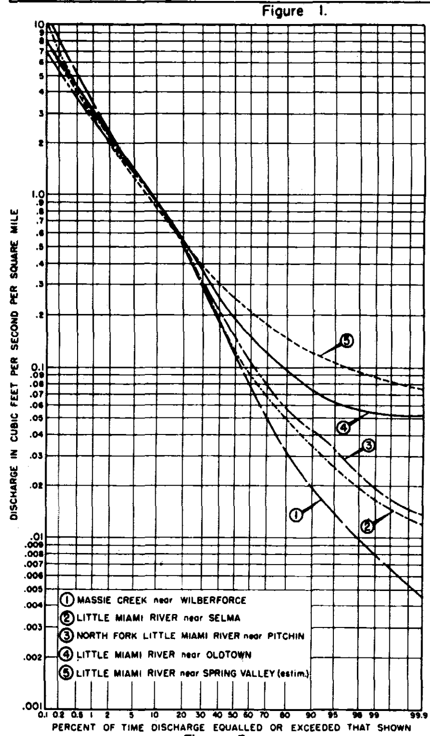

Figure 3.

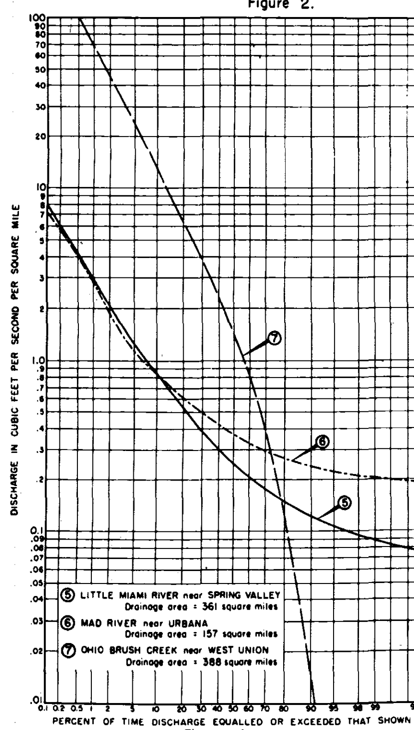

Figure 4.

FIGURE 1. Upper Little Miami basin.
FIGURE 2. Little Miami and adjacent basins.
FIGURE 3. Flow durations, 1953–55, for Upper Little Miami basin.
FIGURE 4. Flow durations, 1953–55, for selected Ohio streams.

The geology of the Little Miami Basin is fairly consistent in its pattern. The consolidated rocks consist chiefly of limestones and dolomites of the Niagara group of the Silurian system which form the bedrock underlying the glacial drift. The formations crop out in several places, most notably near Cedarville, and in the groups near Clifton and Yellow Springs. Overlying the bedrock is glacial drift of varying thickness deposited by the Wisconsin ice sheet of Pleistocene time. These glacial deposits were laid down chiefly as ground moraine, kames, outwash plains, and valley-train deposits. It is the variations in these glacial deposits that have the most pronounced effect on the pattern of sustained streamflow in the basin.

RELATION OF GEOLOGY TO STREAMFLOW

The lowest sustained flows in the Upper Little Miami Basin during the period October 1953 to September 1955 were in Massie Creek which drains an area chiefly of ground moraine consisting of relatively impermeable clay till of varying thickness over-lying and sealing the consolidated rocks of the Niagara group. The geology is reflected in the low-flow index of 0.019 cfs per square mile for Massie Creek near Wilberforce and is equivalent to an average of about 12,000 gallons per day from each square mile of area in the basin. In the extreme upper reaches of the Little Miami River, flow is sustained by seepage from some outwash deposits and kames, along with that from scattered gravel lenses in the glacial till. This situation is reflected in the low-flow index of 0.034 cfs per square mile for the streamflow station near Selma, and 0.042 cfs per square mile for the streamflow station on the North Fork near Pitchin. These flows are roughly twice that in the Massie Creek Basin. Below these stations, the Little Miami River traverses an area of outwash plains above Clifton, and enters a reach of extensive valley train deposits starting about 5 miles upstream from the streamflow station near Oldtown. At that station, the low-flow index has increased to 0.073 cfs per square mile, or about double that of the upstream reaches above Pitchin and Selma. Also contributing to this high sustained flow are the numerous springs occurring at the top of the Osgood and Massie shales, the Springfield and Brassfield limestones, and the Cedarville dolomite which crop out in the area. The most prominent of these springs is Yellow Spring which issues from a fissure in the Cedarville dolomite. The flow of this spring was measured by Bennison (1942) as 60 to 81 gallons per minute during the period June 1941 to May 1942.

Below Oldtown, Massie Creek joins the Little Miami River, and the river continues to traverse the thick valley-train deposits. Outwash plains of considerable extent also sustain the streamflow in this region, particularly in the Beaver Creek Basin, where the low-flow index in September 1948 was determined as 0.38 cfs per square mile, an extremely high figure for Ohio. At the same time, the flow index for Glady Run just above Spring Valley was determined as 0.42 cfs per square mile from an area consisting predominantly of kames, kame moraines, and out-wash plains. The effect of the high sustained flows from Glady Run and Beaver Creek is reflected in the flow duration curve for Little Miami River near Spring Valley. The low flow index for this site is 0.12 cfs per square mile, and is among the highest indices in the State for areas of comparable size. This flow is equivalent to an average flow of more than three-quarters of a million gallons per day from each square mile of drainage area.

COMPARISON WITH OTHER AREAS

For a general comparison of the Little Miami Basin with extremes for Ohio, flow duration curves have been computed for Mad River at Urbana and Ohio Brush Creek near West Union. The location of these basins is shown on figure 2, and the flow duration curves on figure 4. The sustained flow of the Mad River above Urbana occurs from the very extensive gravel deposits throughout the entire basin. The low-flow index at Urbana of 0.24 cfs per square mile is just twice that of the Little Miami River at Spring Valley. This extensive capacity for storage of ground water has been estimated by Cross (1949) as equivalent to a surface reservoir from one to one and one-half times the size of Indian Lake. Ohio Brush Creek, in the southern part of the State, drains an area principally of Illinoian till, and is typical of streams draining relatively impermeable soils. These two curves are indicative of the extremes of flow regimen for Ohio.

The streamflow data cited represent a period of extremely low flow. For example, the low-flow index for the period 1953 to 1955 is 0.24 cfs per square mile for the Mad River at Urbana, whereas for a total period of record of 15 years at this station the low-flow index is 0.33 cfs per square mile. This difference, although quantitatively significant, has an almost negligible effect so far as general comparisons of streamflow regimen are concerned.

SUMMARY

1. The variation in low-flow indices for streams in the Upper Little Miami Basin is controlled principally by the variations in the glacial geology of the area. 2. In general, the magnitude of sustained flow from effluent seepage can be related to the extent of glacial gravels in the basin. 3. Sustained flows in the basin ranged from 0.019 cfs per square mile to as high as 0.42 cfs per square mile in different sub-basins. 4. The Little Miami River has a favorable regimen of sustained flow when compared with other Ohio streams. It is exceeded in Ohio only by the Mad River Basin adjacent to the north and east.

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The results underline how granulometry and mass flow dominance are not distinctive of alluvial fan sedimentation per se and indicate how the critical detection of piedmont, radial palaeomorphology is crucial in the identification of ancient alluvial fans.